Atmos. Chem. Phys. Discuss., 13, C9926–C9930, 2013
www.atmos-chem-phys-discuss.net/13/C9926/2013/

Atmospheric Chemistry and Physics Discussions

ACPD

13, C9926–C9930, 2013

Interactive Comment

Interactive comment on "Middle atmospheric changes caused by the January and March 2012 solar proton events" *by* C. H. Jackman et al.

C. H. Jackman et al.

charles.h.jackman@nasa.gov

Received and published: 12 December 2013

Reply to Referee #1

We thank Referee #1 for helpful comments and suggestions. The "Referee's Comments" are noted first and then we give our "Reply:" to the comment.

Referee 1: In their paper "Middle atmospheric changes caused by the January and March 2012 solar proton events" Jackman et al. describe the effects of two recent SPEs occurred in January and March 2012 on the chemistry of the polar atmosphere. The authors examine both short and long term interhemispheric changes associated to these SPEs, giving a complete overview of the topic to the reader. Observations from different satellites (MLS, MIPAS, ACE) are compared with respect to the Goddard

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

Space Flight Center two-dimensional atmospheric model and results are extensively discussed. Even if several recent publications deal with this topic, the present study stands out for its completeness. Therefore it deserves publication on ACP with only minor corrections. Nevertheless I invite the author to address the following specific comments.

Referee 1 - Specific comments: Pag. 4 lines 23-38 -> Why did you not include the energetic electrons?

Reply: Energetic electrons were not included because there are not reliable measurements of their flux during solar proton events. Protons contaminate the NOAA MEPED instrument's electron energy channels, thus any measurements of the electrons during SPEs are questionable (e.g., see p. 2 of Verronen et al., 2011a and Table 3 of Yando et al., 2011, which was added to the reference list). This is now explained in section 5.3 (paragraph 6).

Referee 1 - In the mesosphere they could be important in the ionization rate computation. Therefore, potentially, you could have slightly underestimated the actual ionization rate. Despite the noise characterizing MLS HO2, figs. 5 and 6 present some clues of a possible underestimation above 0.1 hPa during the January SPE. The same occurs for NOx (fig.12). Nevertheless, the model clearly overestimates HO2 and NOx during the March events. Could you please show some simple sensitivity test reporting for example the observed HO2 profile and the simulated ones under different ionization rates (i.e. increasing the current rate of some, let say, 25, 50, 100, 200 %)?

Reply: We completed several sensitivity studies with the GSFC 2D model in which the SPE ionization rates were increased by 25, 50, 100, 200, and 300%. We focused on the NOx changes (rather than HO2) as those seem to be more evenly affected by such variations. Further, we varied the altitudes at which these ionization rates were changed. The results showed that applying an increased SPE ionization rate of 300% at pressures less than 0.01 hPa resulted in the best agreement between MIPAS and

ACPD
13, C9926–C9930, 2013

the 2D model computations for the January 2012 SPE impacts in the northern polar region (60-90N). However, the comparisons between MIPAS and the 2D model for the southern polar region (60-90S) were made worse. Also, we have now rerun the base and perturbed simulations with the Global Modeling Initiative (GMI) three-dimensional (3D) chemistry transport model (CTM) model (see sections 4.3 and 4.4) and find similar agreement with MIPAS data as previously shown for the 2D model. Thus, we have not added any discussion of these sensitivity studies to the paper.

Referee 1 - The ionization computation strongly depends on the specific satellite and the fit function used. In this study protons from GOES 13 have been employed in the simulation of both January and March events. Does the use of a different fit function could significantly improve the results for the March SPE?

Reply: A different fit function to the proton flux can change the ultimate NOx production due to an SPE. For example, we fit the proton fluxes for the January and March 2012 SPEs with three power law forms [Flux(E) = Fo E^(Eo)] for the 1-10 MeV, 10-50 MeV, and 50-300 MeV bands. We then compared the production of NOx to our baseline computations using our usual exponential forms [Flux(E) = Fo exp(-E/Eo)] for those same energy bands. We computed about a 25% reduction in NOx using the power law form compared with using the exponential form. Use of the power law fit would slightly improve the model/measurement agreement for March 2012. It should be noted that we underestimate (overestimate) the NOx production for the northern (southern) polar region in January and overestimate the NOx production for both the southern and northern polar regions in March with the GSFC 2D model and GMI 3D CTM computations. Given these somewhat conflicting differences between the model computations and measurements, it is difficult to definitively conclude that a different fit function of the proton flux is required.

Referee 1 - Pag. 8 lines 26-27 -> the inter-hemispheric differences under similar solar radiation conditions could be an interesting issue. If possible, I would see these figures. Perhaps you could include them only in the interactive discussion section.

ACPD
13, C9926–C9930, 2013

Reply: We now include the HO_2 change in March 2012 for both polar hemispheres in Figure 4 (see discussion in section 5.1, paragraphs 5 and 6).

Referee 1 - Pag. 9 lines 11-12 -> indeed, one could expect more SPE-induced production of HOx in SH due to the higher ambient H_2O; nevertheless, this should be valid for both observations and model predictions.

Reply: Agreed. We now include a sentence on this in section 5.1 (paragraph 6).

Referee 1 - Pag.10 lines 8-10 -> despite the slightly different latitudinal band presented in von Clarmann et al 2013, actually also MIPAS seems to show O_3 enhancement at the end of January.

Reply: Thanks for this observation. We have modified our discussion in section 5.2 (paragraph 3) to reflect this.

Referee 1 - Pag.14 lines 9-11 -> Despite the shorter duration, the magnitude of the O_3 changes seem to be comparable to the changes induced by the solar irradiance variation. Could SPEs modulate the radiative solar cycle effect in a significant way?

Reply: It is true that the SPE-caused O_3 changes can be competitive with the solar irradiance variations over a limited latitude region (high latitudes) and for a limited period of time (several months). We have now added some lines discussing this issue in section 6 (last paragraph).

Referee 1 - The paper includes 19 figures, perhaps too many. You could join some of them. For example figs. 1-4 could be easily reduced to two; then you could join figs 5 and 6, figs. 8 and 9 and so on.

Reply: We have greatly reduced the number of figures by joining many together. We have added one figure addressing one of the issues (Figure 4, see discussion above). We also removed two figures: 1) the figure showing the ratio of total HOx concentrations from the Southern to the Northern Hemispheres for January; and 2) the figure showing the model predicted total ozone change. These figures are probably not necessary. The ratio of total HOx concentrations from the SH to the NH for January and the SPE-caused total ozone changes are still discussed in the manuscript. We now have a total of 12 figures.

Interactive comment on Atmos. Chem. Phys. Discuss., 13, 23251, 2013.

ACPD

13, C9926–C9930, 2013

Interactive Comment